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An Evaluation of Compact Laser Drivers for Field-Deployed, Analog Fiber-Optic Systems

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14. ABSTRACT

Various laser drivers are analyzed experimentally to determine the impact on the performance of an analog photonic link. For field-deployed units, the NRL-designed supply provides superior noise performance over commercial devices, but the lowest noise is achieved via a bench-top low-noise laser driver.

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EXECUTIVE SUMMARY

- The features and use of the LDTC0520, LDTC1020, LDTC2/2, and NRL-designed supply are explained.
- The system setup and required equations for RIN measurements are presented.
- The RIN of an EM4 253 Semiconductor Laser is measured using each controller.
- The benefits and shortcomings of each controller are given.

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AN EVALUATION OF COMPACT LASER DRIVERS FOR FIELD-DEPLOYED, ANALOG FIBER-OPTIC SYSTEMS

1 INTRODUCTION

An increasing amount of systems implementing radio-frequency (RF) hardware are converting to fiber optic systems. Fiber is lighter, more flexible, has lower attenuation, higher bandwidth, and it is immune to electromagnetic interference. Applications using fiber such as antenna remoting [1],[2] and optoelectronic oscillators [3] have shown significant improvements over standard RF equipment. Photonic systems have also been implemented in wideband signal processing and manipulation for electromagnetic warfare and radar demands [4],[5]. The performance of these photonic links depends heavily on the amount of noise generated by the lasers. Much of this noise is not caused by the laser itself but is due to the laser controller. This report will discuss the setup and operation of several laser drivers and look at their contribution to the overall noise.

The FL500 [6] is a 500mA laser diode driver which is small in size and low in power consumption. This makes it ideal for applications outside of the lab. It also boasts several features such as brownout protection and slow start laser diode protection. Another key feature is that it can be configured as two independent 250mA drivers instead of a single 500mA driver, potentially removing the need for a second driver in some systems. Consult the FL500 datasheets supplied by Wavelength Electronics Inc. for more information regarding its specifications and operating modes. [6] The focus of this report lies on the LDTC0520, LDTC1020, and NRL-designed “cup supplies”, which utilize the FL500 driver. The LDTC2/2 and LDC-3742 controllers do not use this chip.

The LDTC0520 and LDTC1020 [7] (also products of Wavelength Electronics) are essentially commercial versions of the in-house cup supplies. They differ in that they allow the user to control the device remotely, give more freedom when configuring the controller, and can be set to run in either constant power or constant current modes. The cup supplies, on the other hand, are a more rudimentary controller in that the only adjustable settings are the current supplied to the laser diode and the temperature setpoint. However, the cup supplies only require two power supplies (one +5V and one -5V) whereas the LDTC0520 and LDTC1020 require three supplies (voltages vary depending on operating conditions). The LDTC2/2 is similar to the other LDTC models in operation, but it differs in the amount of current it can supply to the laser diode.

The in-house cup supplies will be described in detail in Section 2 of this report. Section 3 will focus on the use of the LDTC0520/1020 and their various settings. Section 4 will briefly describe the differences between the LDTC2/2 and the LDTC0520. The RIN measurements of an EM4 253 (1550nm) laser driven by each controller will be presented in Section 5. These data will be compared to measurements taken using a bench top Lightwave LDC-3742 laser diode controller. Finally, Section 6 will summarize the key aspects of each controller and give insight into when each should be used.

2 FL500 CUP SUPPLIES

The in-house cup supplies were designed for simple applications which would not require external control or monitoring. The power is supplied via two pads and their corresponding grounds. The laser diode and TEC are supplied by -5V and +5V sources, respectively. The current supplied to the laser diode and the temperature at which the laser will operate are set by adjusting two trimpots on the supply. See Figure 1 for the locations of the current and temperature controls.

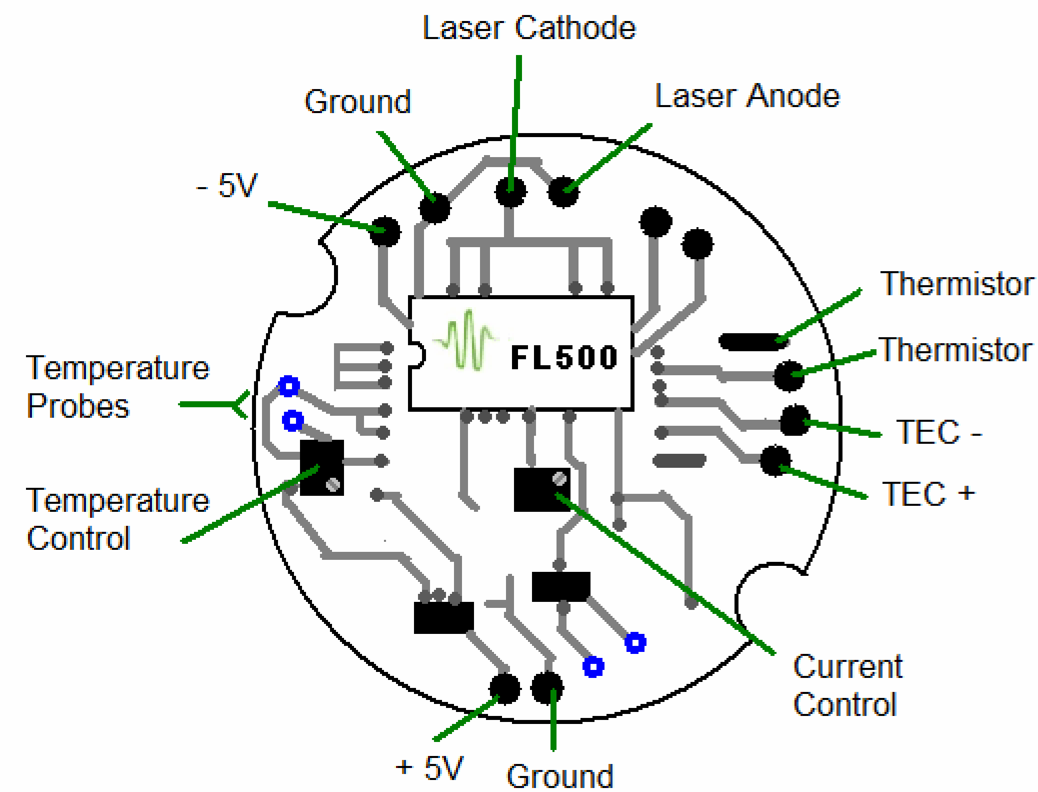

Figure 1: Diagram of an in-house FL500 cup supply. The connection pads for the laser hookup and power supplies are labeled. Also labeled are the current and temperature controls. The operating temperature of the laser diode can be determined by measuring the voltage across the temperature probes. The conversion factor between the measured voltage and temperature is given later in this document.

Supplying Power – Two sources are required to power the cup supply. One -5V source (for the laser diode) and one +5V source (for the TEC). Deviating from these values was found to reduce noise performance. The laser diode will draw between 0 and 500mA (depending on where the trimpot is set), and the TEC will draw any current up to 2.5A. In the laboratory environment, a temperature setting of 22.7°C was maintained with approximately 300mA of current supplied to the TEC.

Current Control – Turning the trimpot clockwise reduces the amount of current supplied to the laser diode. Note: exceeding 500mA of current could damage the FL500.

Temperature Control – Turning the trimpot clockwise lowers the operating temperature of the laser diode

Temperature Measurement – To determine the temperature of the laser diode, measure the voltage between the thermal probes. Figure 2 gives the conversion between measured voltage and operating temperature.

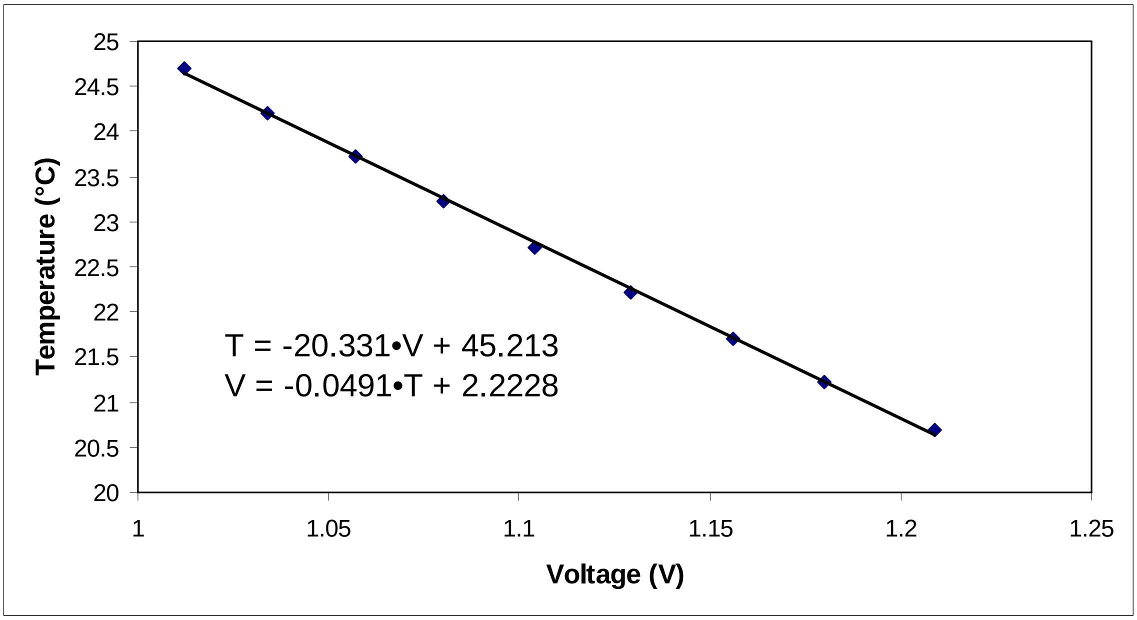

Figure 2: Temperature as a function of measured voltage. For small temperature ranges, the curve is linear. For 20 to 25°C, the equations above are accurate within 1%.

3 LDTC0520 and LDTC1020 CONTROLLERS

The LDTC0520 and LDTC1020 are essentially the same controller. The only difference is that the LDTC1020 can supply up to 1A to the laser, whereas the LDTC0520 can only supply 0.5A. Due to this similarity, this section will address the LDTC0520 only (the information pertains to the LDTC1020 as well, unless otherwise noted).

Like the in-house cup supplies, the LDTC0520 allows the user to adjust the temperature and current. In addition to this, it allows the user to adjust the currents used by the TEC for heating and cooling individually. Another unique feature is the constant power mode, which adjusts the current in real time to ensure the laser's power output remains constant. Perhaps the most significant advantage the LDTC0520 has over the cup supply is its ability to be controlled remotely. These extra features come at the cost of an additional power supply, however.

CHECK THAT THE LASER DIODE WHICH IS TO BE POWERED BY THIS CONTROLLER DOES NOT CONTAIN A THERMAL SENSOR WHICH IS GROUNDED TO THE CASE. LASER DIODES WITH CASE-GROUNDED THERMISTORS ARE NOT SUPPORTED BY THE LDTC0520.

The LDTC0520 has three connectors: one for the power input, one connects directly to the laser, and the third can be used to connect the controller to a computer for external control. Like the cup supply, trimpots are used to adjust the various settings. The LDTC0520 and LDTC1020 each have a toggle switch which allows the user to power the controller but not the laser diode. This is something that cannot be done with the in-house cup supply. See Figure 3 for a diagram of the LDTC0520/1020.

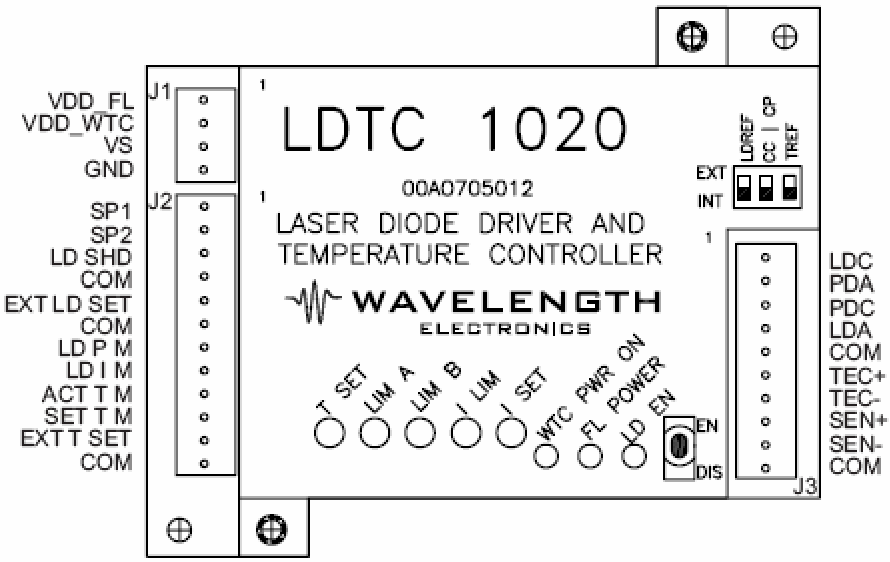

Figure 3: Top down diagram of the LDTC0520/LDTC1020. [7] Connectors J1, J2, and J3 are for the input power, external control, and laser connection respectively. Three switches on the top right corner of the device toggle between internal and external control, as well as change between constant power and constant current modes. Also seen are the control trimpots and the LED indicators.

3.1 Applying Power

Check that the toggle switch is set to the DIS (disengage) position before applying power to the controller. Connector J1 has four pins: pin 1 (VDD_FL) supplies power to the laser diode, pin 2 (VD_WTC) powers the control electronics, pin 3 (VS) powers the TEC, and pin 4 (GND) is the ground for pins 1-3.

Pin 1 (VDD_FL) – This pin requires +3V to +12V. The amount of current drawn will depend on where the trimpot is set (more on this later). The voltage applied should be as high as possible without exceeding the power dissipation limit of the FL500. See the data sheets supplied by Wavelength Electronics, Inc. or use their online Safe Operating Area (SOA) calculator at http://www.teamwavelength.com/tools/calculator/soa/defaultld.htm for more details on calculating the maximum voltage which can be applied without risking heat damage.

Pin 2 (VD_WTC) – Apply +5 to +28V to supply the control electronics. The current drawn by this pin is minimal, so overheating is not an issue. Unlike pin 1, the voltage applied to this pin should not be as high as possible, as it does not improve performance.

Pin 3 (VS) – This pin requires +5 to +28V. It can draw up to 2.2A, so heat dissipation becomes a major issue at higher voltages. In this case, you want to have VS as low as possible (keep it at least 2V above the level required by the TEC, however). Again, consult the datasheets or use their online SOA calculator to ensure the chosen level does not exceed the safe operating conditions.

Pin 4 (GND) – This is a high current ground to be used with pins 1-3.

3.2 Temperature Control

It is highly recommended that the temperature settings are set and tested prior to sending power to the laser diode. Turning the T SET trimpot clockwise lowers the temperature at which the laser diode will operate. To check the current setting, measure the voltage between pins 10 and 12 of the J2 connector. To check the actual temperature of the laser diode, measure the voltage between pins 9 and 12 of the J2 connector. See Figure 2 on page 4 for instructions on obtaining the temperature from the measured voltage.

The current limits to the TEC must be set next. LIM A and LIM B limit the amount of current the TEC can draw to cool and heat the laser diode respectively. Clockwise rotation increases the current available to the TEC. The datasheets do not mention a way to measure the current limits. This means that the user will have to watch the temperature of the laser diode and adjust these limits if the TEC fails to keep the temperature stable.

3.3 Current Control

There are two trimpots which limit the amount of current being supplied to the laser diode. I LIM limits the maximum amount of current the laser can draw. This is needed in constant power mode, as it can be set to prevent damage to the FL500 or the laser diode. The second trimpot, I SET, adjusts the current supplied to the laser in constant current mode. Note that if I LIM is lower than I SET, the laser will be limited to the value set by I LIM, even in constant current mode. For all practical purposes, I LIM should be set to the current limit specified by the laser (not to exceed the 500mA threshold of the FL500). As before, clockwise rotation increases the available current.

To measure the value of I SET, measure the voltage between pins 8 and 12 of the J2 connector. The set current is equal to 500mA per Volt. The value of I LIM can be measured from a probe inside the casing. The probe is located directly above the upper left corner of the I LIM trimpot. The value of I LIM can be measured when there is no power being sent to the laser diode. I SET, however, can only be measured once the toggle switch is in the EN (engage) position. The value of I LIM should be set prior to activating the laser diode, as it will prevent damage to the FL500 or the laser diode itself.

3.4 Starting the Laser

At this point the system should have power (the first two of the three LED indicators should be on), and the temperature and current settings should be configured correctly.

All that is left is to send power to the laser diode. This is not as simple as flipping the toggle switch to the EN position, however. Pin 3 of connector J2 must first be grounded to pin 4. If the device is being controlled externally, the toggle switch will be left in the EN position, and the system will be powered up and down through these two pins. If the device will not be controlled externally, a jumper can be placed between pins 3 and 4, and the toggle switch will be used as the power on.

After grounding pin 3, flip the toggle switch to the EN position, and check that the third LED indicator has come on. Recall that the current traveling to the laser diode can be measured by taking the voltage between pins 8 and 12. There are 500mA per Volt measured traveling to the laser. Adjust the I SET trimpot until the required current is being supplied.

The temperature should also be watched closely for the first few minutes of operation. If the laser is running at a different temperature than that dictated by T SET, try adjusting LIM A or LIM B (whichever is appropriate) to allow more current flow to the TEC.

3.5 Operating Modes

The LDTC0520 has three switches located above connector J3 which allow the user to alternate operating modes. The first and last of these switches toggles between internal/external current and temperature control respectively. The centermost switch sets the device to work in either constant power or constant current mode.

Current Control – The first of the three switches (LDREF) alternates between internal and external current control. When internal control is selected, the current output to the laser is dictated by the I SET trimpot. For external control, 0-2V can be applied between pins 5 and 6 of connector J2. The transfer function is 250mA per volt in constant current mode, and 1mA of photodiode current per volt in constant power mode.

Temperature Control – The third switch (TREF) allows the user to control the temperature through the internal trimpot, or an externally supplied voltage. In external mode, a desired temperature can be reached by applying the corresponding voltage between pins 11 and 12. See Figure 2 for details on selecting the appropriate voltage. Should the voltage drop below 0.3V, the temperature will automatically revert to 25°C.

Constant Current Mode – The second switch (CC | CP) toggles between constant power and constant current modes. In constant current mode, the controller applies a set amount of current to the laser. This current will be the value given by I SET (or I LIM if it happens to be lower than I SET).

Constant Power Mode – In constant power mode, the current supplied to the laser diode is adjusted in an attempt to provide a constant power output. This is achieved by monitoring the power reported by the laser's internal photodiode. The current supplied to the laser can range anywhere from 0 to the value set by I LIM. It is important that I LIM be set to a safe limit to prevent damage to the laser diode or the FL500.

4 LDTC2/2 CONTROLLER

The LDTC2/2 is very similar to the LDTC0520 in setup and operation. This section will discuss applying power to the device and mention some observed deviations from the instructions offered in Section 3.

Applying Power – The LDTC requires 2 power supplies. +5V can be applied to pins 1 and 2 (grounded to pin 3). For values higher than +5V, consult the datasheets [8] for the SOA for this device. Each pin is capable of drawing up to 3A of current, so it is important to have an adequate power supply.

Observed Differences

There are several important differences between the LDTC2/2 and the LDTC0520. The first is that, unlike the LDTC0520, turning the I LIM trimpots clockwise reduces the available current. Another observation is that the toggle switch is ineffective if the jumper is in place between pins 3 and 4. Unlike the LDTC0520 which required the toggle switch be on AND pin 3 be grounded, the LDTC2/2 requires one or the other, not both.

The location of the constant current/power switch has been moved to a stand-alone switch located on the side of the unit. Furthermore, the internal/external temperature and current switches have been replaced with jumpers. Consult the datasheets to set the device to be controlled externally (the device should be internally controlled by default).

One final note is that the connectors J2 and J3 on this device are identical to those on the LDTC0520, they are just located on the side of the device.

5 NOISE MEASUREMENTS

This section will compare the noise levels of the in-house cup supply, LDTC0520, LDTC1020, LDTC2/2, and Lightwave LDC-3742 (with and without an electrical filter) controllers. The experimental setup can be seen in figure 4.

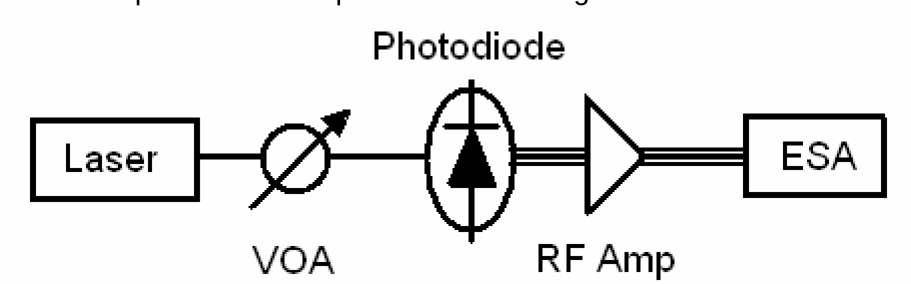

Figure 4: Experimental setup for measuring the Relative Intensity Noise (*RIN*) of a particular source. A laser (an EM4 253 1550nm was used for these measurements) sends light through a Variable Optical Attenuator (VOA), onto a detector (DSC50S for this experiment). The detector's output is amplified using a low-noise electrical amplifier (Sonoma 310), and examined using an Electrical Spectrum Analyzer (Agilent 8563EC).

It should be noted that the Lightwave LDC-3742 controller is rather large. It is an excellent controller for in-lab measurements, but cannot be used easily for deployed systems. It is used to demonstrate the effects electrical noise has on the RIN of a laser.

Measurements were taken in decades starting from 10kHz and ending at 1GHz. Before measurements were taken, the individual controllers were set for 80mW of output power, and optimized for a low noise level. The temperature setting of each controller was set to 22.7°C (as specified by the laser's datasheets). The total noise of the system is given by

$$N_{\text{total}}[\text{dBm/Hz}] = N_{\text{meas}}[\text{dBm}] - 10\log(RBW[\text{Hz}])\,, \tag{1}$$

where N_{meas} is the value obtained from the ESA, and *RBW* is the resolution bandwidth used during the measurements. The equations for RIN derived in [9] are

$$RIN[\text{dBm/Hz}] = 13 + N_{\text{total}}[\text{dBm/Hz}] - 20\log(I_{\text{dc}}[\text{mA}]) \tag{2}$$

and

$$RIN[\text{dBm/Hz}] = 19 + N_{\text{total}}[\text{dBm/Hz}] - 20\log(I_{\text{dc}}[\text{mA}]) \text{ (for matched load)}, \tag{3}$$

where I_{dc} is the dc photocurrent. The RIN of this particular system can be calculated using (3) and the measured noise. The results can be seen in Figure 5.

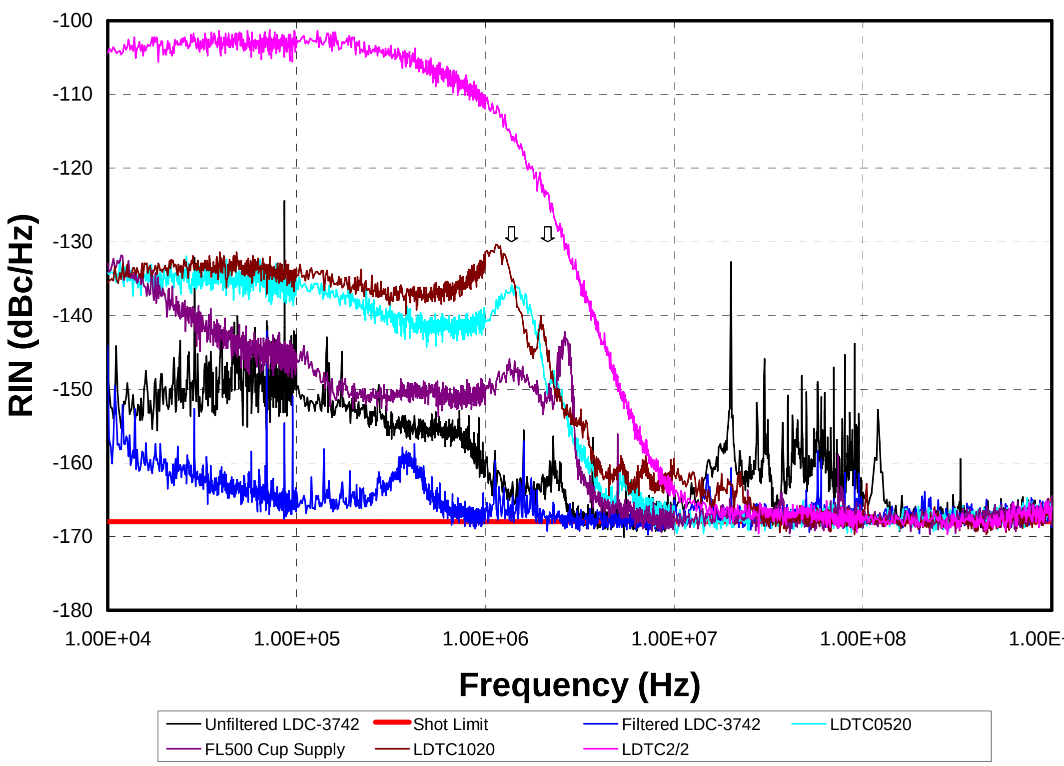

Figure 5: RIN measurements for the individual controllers. The red line shows the shot noise of the system. By comparing the black (Unfiltered LDC-3742) to the dark blue (Filtered LDC-3742), one can observe just how much electrical noise influences the RIN of the source.

It can be seen that the LDC-3742 with an attached electrical filter gives the best performance. However, as stated earlier, this controller can not be easily included in deployable systems. The LDTC2/2 has a relatively high noise level for frequencies below 10MHz, making it a poor choice for systems in this range. Two broad peaks can be seen around 3-5MHz on the cup supply, LDTC1020, and LDTC0520's RIN plot. These can most likely be attributed to the FL500 chip, as it is used in each of the three systems. In the end, it appears as though the cup supply has a better noise performance than any other deployable controller. However, for systems operating above 10MHz, the system is shot noise limited.

6 Conclusions

A detailed discussion of the in-house cup supply, LDTC0520, LDTC1020, and LDTC2/2 have been presented. The setup and operation procedures discussed in sections 2, 3, and 4, as well as the noise measurements presented in section 5 allow us to choose which controller would best fit any application. The in-house cup supplies give better noise performance at frequencies under 10MHz and operate at a lower power than the commercial versions. However, the commercial controllers must be used if the system requires external control or constant power operation. Having a laser with the thermal sensor grounded to the case is the only situation in which a cup supply must be used (the LDTC0520 and LDTC1020 do not support these laser packages). The LDTC2/2 is a poor choice for any system which does not require a large amount of current due to its large power consumption and high noise below 10MHz.

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